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(54) A temperature responsive display device

(57) A temperature responsive display device 1 e.g. in the form of a fever scope, comprises a light absorbing layer and arranged, e.g. printed, in front of the latter, at least two thermochromic liquid crystal compositions (3a-b, 4a-b, 5) having different clearing points which mask the backing layer, at least one of the clearing points being chosen to be in the normal operating temperature of the display device. In use, the display visible is provided by the contrast between any thermochromic liquid crystal composition 8 which has not been rendered transparent and the light absorbing backing layer visible directly or through portions 7 of the overlying liquid crystal compositions which have been rendered transparent. As shown for use on a forehead, three different thermochromic liquid crystal layers clear at 34.5°C, 36°C and 45°C over a black backing layer. Above 34.5°C 'N' clears to show black on a green area 8. At 36°C, 'F' and area 11 remain green while area 10 is black. At 45°C, area 14 clears to leave 'F+' green. In a room thermometer, Fig 5 (not shown) the black backing layer is uncovered gradually in thirteen steps to represent a rising black line from a bulb area.

FIG. 2

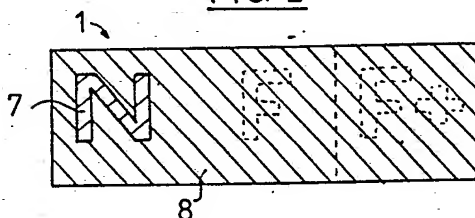


FIG. 3

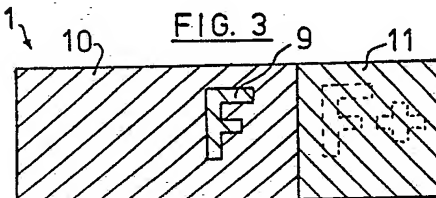
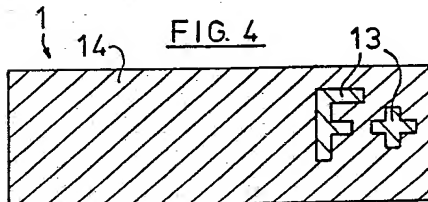


FIG. 4



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FIG. 1A



FIG. 1B

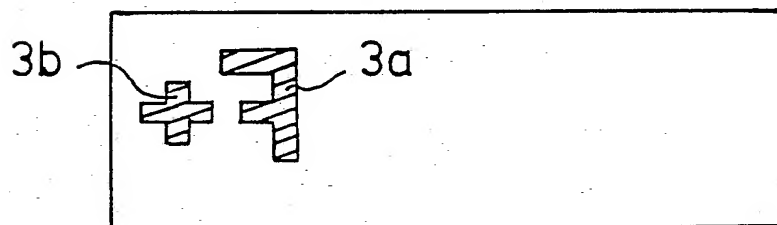


FIG. 1C

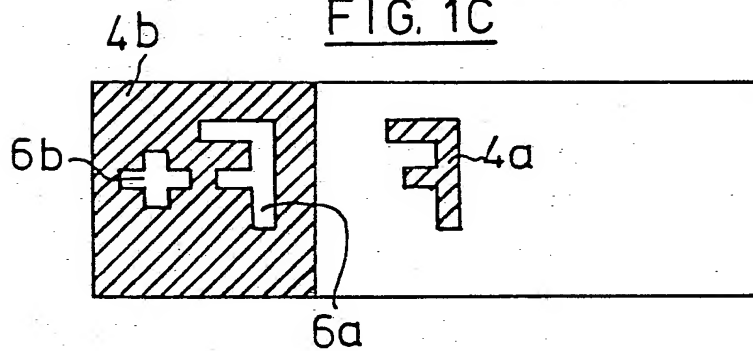
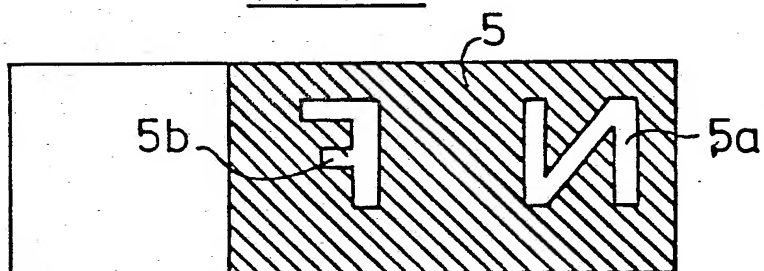


FIG. 1D



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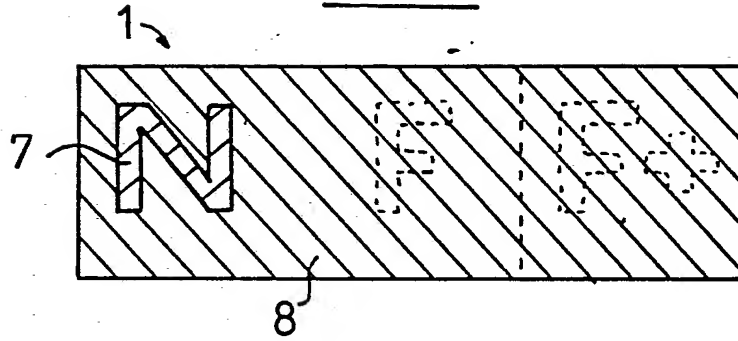
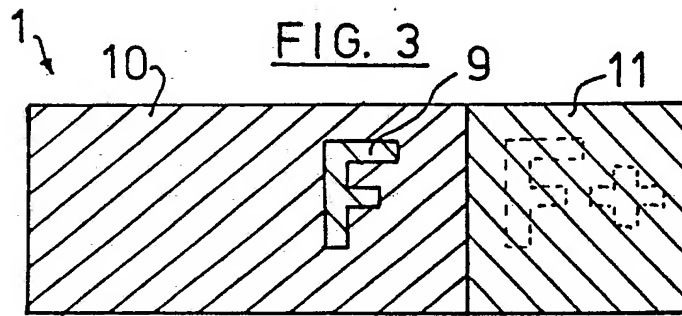
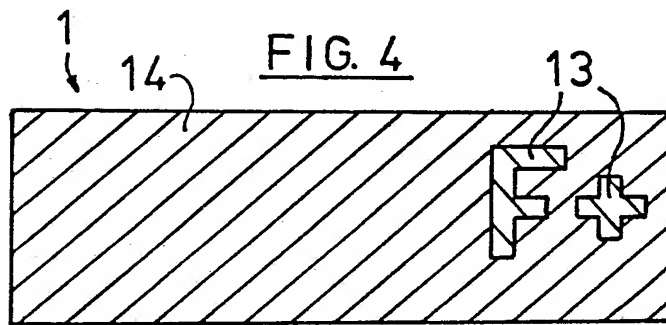
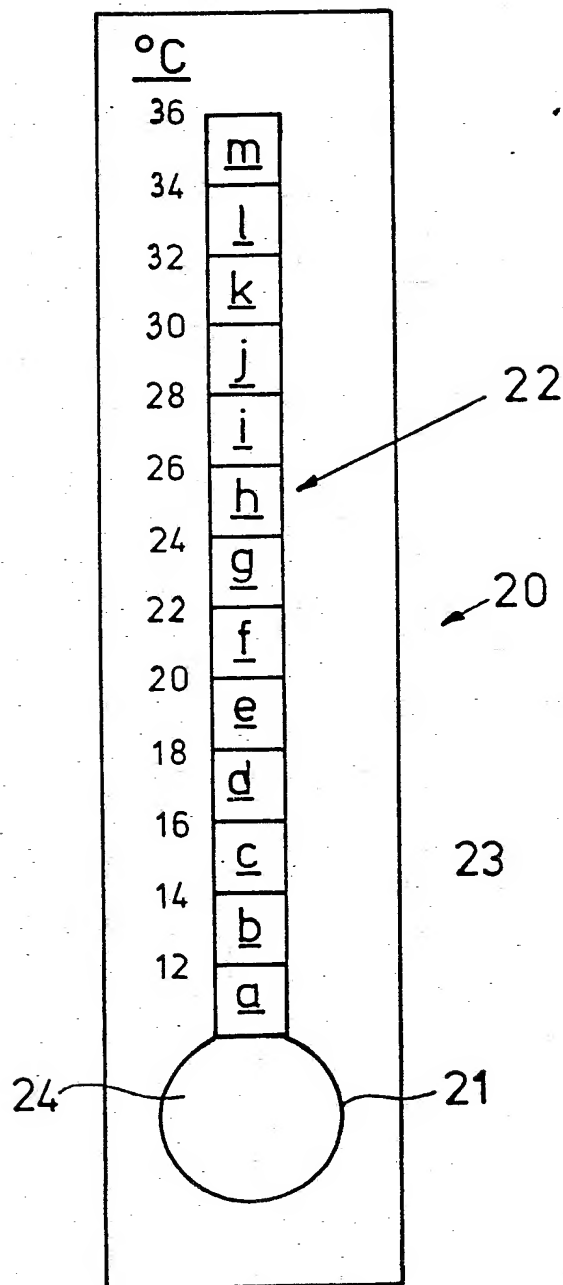
FIG. 2FIG. 3FIG. 4

FIG. 5

A temperature responsive display device

This invention relates to a temperature responsive display device comprising at least two thermochromic liquid crystal compositions.

Thermochromic liquid crystal compositions are well known and heretofore have been employed in a wide range of temperature sensing applications, e.g. in thermometry as digital thermometers or fever scopes or in thermography. These known applications make use of the fact that a thermochromic liquid crystal composition can exist in a cholesteric phase in which the composition has temperature dependent optical properties.

Typically a thermochromic liquid crystal composition can exist in a smectic phase or the cholesteric phase between its crystal state and its isotropic state. When in the smectic phase, a thermochromic liquid crystal composition is virtually transparent and reflects virtually no light. On heating the composition after transition from the smectic phase to the cholesteric phase the thermochromic liquid crystal composition displays thermochromism, undergoing a "colour play", e.g. from "start of red" to "start of blue" in the visible spectrum. The temperature over which this colour play takes place is known as the colour play temperature range. As the thermochromic liquid crystal composition is heated further it eventually undergoes a transition from the cholesteric phase to its isotropic state in which state the composition is substantially transparent and reflects virtually no light. The temperature at which the liquid crystal composition undergoes the transition from a liquid crystal phase, e.g. the cholesteric phase, to the isotropic state is known as the "clearing point".

Other types of thermochromic liquid crystal compositions are known which have a low temperature dependence

of colour, the liquid crystal composition appearing as a substantially constant colour, e.g. light green, in reflected white light over a comparatively wide temperature range immediately below the clearing point of the thermochromic liquid crystal composition.

Thermochromic liquid crystal compositions are also known which exhibit "memory" for a period of time when, after being heated above the clearing point, the temperature of the composition is lowered below the clearing point. Thus, for example, with a thermochromic liquid crystal composition having a low temperature dependence on colour and having "memory", the composition may display a different colour for a period of time, e.g. from 5 seconds to 30 minutes, after the temperature of the composition is lowered below the clearing point compared with the colour of the composition immediately prior to elevating the temperature of the composition above the clearing point.

In known temperature responsive display devices, employing at least two different types of thermochromic liquid crystal compositions, the liquid crystal compositions are viewed through windows of a permanently opaque mask. For example a known fever scope comprises a flexible, front carrier sheet, e.g. of plastics film, having a permanently opaque, e.g. black, masking layer printed thereon. This masking layer has windows, e.g. in the form of letters "N" and "F", formed therein. First and second thermochromic liquid crystal compositions having different colour play temperature ranges, e.g. from 33°C - 35°C and 35°C - 40°C, respectively, are applied behind the masking layer so that the first composition covers the "N" window and the second composition covers the "F" window. A final backing layer, preferably black, is applied over the two thermochromic liquid crystal compositions. In use of this known fever scope, the

backing layer is placed against a user's forehead and the first and/or second thermochromic liquid crystal compositions display thermochromism in dependence on the temperature sensed which is visible through the permanently opaque masking layer. Depending on the colour of the "N" and/or "F" visible through the masking layer, a representation of the user's forehead temperature (typically 2-2.5°C less than the user's internal body temperature) is obtained. In this known device the colour play properties of the thermochromic liquid crystal compositions are employed in conjunction with a permanently opaque, windowed masking layer in front of these compositions.

The present invention seeks to provide an alternative form of temperature responsive display device incorporating at least two thermochromic liquid crystal compositions having different clearing points.

According to the present invention, there is provided a temperature responsive display device comprising a light absorbing backing layer and, arranged, e.g. printed, in front of the latter, at least two thermochromic liquid crystal compositions having different clearing points which mask the backing layer, at least one of the clearing points being selected to be in the normal operating temperature range of the display device, whereby, when the display device is subjected to incident light and the temperature of the display device is elevated from a temperature below the lowest clearing point to a temperature above the highest clearing point, an increasing proportion of the backing layer is revealed as the various clearing points are passed through, the display visible at any stage of the temperature elevation being provided by the contrast between any thermochromic liquid crystal composition which has not been rendered transparent and the light absorbing backing layer visible directly or through portions of the overlying liquid crystal compo-

sitions which have been rendered transparent.

Preferably the thermochromic liquid crystal compositions are of the type which have a low temperature dependence of colour. Such compositions are preferably
5 selected to display the same colour over wide temperature ranges immediately below their respective clearing points when subjected to incident white light. This colour, e.g. light green, is chosen to have a high contrast with the light-absorbing backing layer which is preferably
10 coloured black. Since the thermochromic liquid crystal compositions clear immediately as their temperatures are raised through the clearing points, precise switching of information on the display device is obtained as the temperature of the device is raised through the
15 various clearing points. This is particularly advantageous over display devices which operate on the "colour play" of thermochromic liquid crystal compositions, the latter displaying information over a range of temperatures of the colour plays instead of switching information
20 at precise temperatures.

In certain applications the thermochromic liquid crystal compositions employed are of the "memory" type, each composition having a "memory" for a period of time, e.g. from 5 seconds to 30 minutes, after its temperature
25 is lowered below its clearing point. Such "memory" can be provided by the addition of known cholesteric additives in the thermochromic liquid crystal compositions. Alternatively the liquid crystal compositions can be sandwiched between sheets of high thermal inertia material. With
30 such high thermal inertia material the type of material and its thickness determine the particular "memory". For an oral thermometer, the "memory" may last for approximately 15 seconds to enable the thermometer to be read after it has been withdrawn from the mouth. To achieve
35 such a "memory" with high thermal inertia material, the

material, which may be convenient types of plastics material, will typically have a thickness of about 750 μm .

Embodiments of the invention will now be described, by way of example, with reference to the accompanying
5 drawings, in which:

Figures 1A to 1D are schematic representations of four different layers printed onto a flexible, transparent, front carrier sheet of a temperature responsive display device according to the invention in the form
10 of a fever scope;

Figures 2 to 4 are schematic plans of various representations illustrated by the fever scope of Figures 1A to 1D at different temperatures; and

Figure 5 is a view of a thermometer type device
15 illustrating a different application of a temperature responsive device according to the invention.

Figures 1A to 1D show the various stages in the manufacture of a fever scope 1, each figure illustrating the different layers which are printed onto the inner
20 surface of a thin, flexible, transparent upper or outer layer 2, e.g. a sheet of PVC or other plastics material. This outer layer 2 may be gloss or matt surfaced and is conveniently surface modified to eliminate static and to enable specially developed ink systems to key
25 directly onto the modified surface during printing, e.g. using a web offset lithographic process. Such surface modified PVC film is known in the printing art.

Firstly any graphics and/or written matter (not shown) and intended to be viewed through the upper or
30 outer layer 2 is printed onto the inner surface of the outer layer 2 by a conventional printing process, e.g.

by a web offset lithographic process. Next three different thermochromic liquid crystal compositions are printed onto the layer 2 in three separate printing operations; a first thermochromic liquid crystal composition being
5 applied in two regions 3a and 3b (see Figure 1B), a second thermochromic liquid crystal composition being applied in two regions 4a and 4b (see Figure 1C) and a third thermochromic liquid crystal composition being applied in a single region 5 (see Figure 1D). In Figures 1B
10 to 1D the different regions of thermochromic liquid crystal compositions applied successively to the inner or back surface of the layer 2 are designated by hatched lines. In these Figures, the regions are shown as reverse or mirror representations, but when viewed from the front
15 will appear as normal characters "N", "F" and "+". The region 4b of the second thermochromic liquid crystal composition is shown provided with two windows 6a and 6b therein in the form, respectively, of a reverse or mirror letter "F" and a sign "+". These windows 6a and
20 6b are intended to register with the regions 3a and 3b, respectively, but it will be appreciated that the windows may be slightly undersized or omitted all together so that the region 4b overlaps the regions 3a and 3b. The region 5 is also shown provided with two windows 5a and
25 5b in the form of reverse or mirror letters "N" and "F", respectively. The window 5b is intended to register with the region 4a, but it will be appreciated that this window 5b can also be slightly undersized or omitted all together so that a portion of region 5 overlaps the
30 region 4a. Of course by providing windows which are filled by underlying printed regions, it is possible to reduce the amount of thermochromic material printed onto the layer 2.

In a final printing operation, e.g. by a web offset
35 lithographic process, a light absorbing backing layer (not shown), e.g. of black ink, is applied over the entire

surface area of the layer 2 which already has the thermochromic liquid crystal compositions printed thereon.

After the printing operations, a backing sheet (not shown), e.g. of plastics material, is adhered to the printed layer 2 so as to cover the light absorbing backing layer and sandwich the liquid crystal compositions between the backing sheet and the outer layer 2. This backing sheet and the outer layer 2 typically each have high thermal inertia and a thickness of about 750 μm so as to provide the fever scope 1 with a degree of "memory".

When the fever scope 1 is viewed from the front it will be appreciated that the backing sheet forms the back of the fever scope and the layer 2 forms the front of the fever scope. When viewed from the front, the light absorbing backing layer is masked by the regions 3a, 3b, 4a, 4b and 5 over its entire area apart from the unmasked area provided by the window 5a.

The thermochromic liquid crystal compositions are in the form of printing inks, in particular the thermochromic liquid crystal compositions being microencapsulated as is well known in the art. The microcapsules preferably have a diameter of less than 20 μm , more preferably a diameter of from 10 - 15 μm , so that the printed regions 3 - 5 can be printed in thin layers, typically 20 μm thick, by known printing techniques, e.g. by a web offset lithographic process. The liquid crystal inks may be printed directly onto the layer 2. Alternatively a "tie coat" may be printed onto the layer 2 before the liquid crystal inks are printed thereon to improve the adhesion of the printing inks to the layer 2.

The three thermochromic liquid crystal compositions are characterised in that they possess different clearing

points and in that they possess a low temperature dependence of colour. In particular the thermochromic liquid crystal compositions are selected so that when the various printed regions are subjected to incident white light, they display substantially the same colour, e.g. light green, over a comparatively wide temperature range immediately below their respective clearing points. The colour displayed is dependent on the particular thermochromic liquid crystal compositions and can be selectively chosen. However the displayed colour should have a high contrast with the light absorbing, preferably black, backing layer (not shown). Thermochromic liquid crystal compositions having a low temperature dependence of colour are described in an article by Dr. D.G. McDonnell entitled "Thermochromic Liquid Crystals" published by BDH Chemicals Limited. Such a composition can be prepared by mixing liquid crystal compounds. For example, the composition may comprise a mixture of chiral nematic liquid crystal compounds mixed in proportions to adjust the clearing point of the composition and a nematic liquid crystal compound mixed in a proportion to adjust the colour of the composition in its cholesteric phase. Typically the chiral nematic liquid crystal compounds comprise TM74 and TM75 (available from BDH Chemicals Limited), and the nematic liquid crystal compound comprises ME35 (also available from BDH Chemicals Limited). As previously described the liquid crystal compositions are sandwiched between high thermal inertia materials to provide the fever scope with "memory". However alternatively or in addition, "memory" can be provided by the addition of known cholesteric additives to each thermochromic liquid crystal composition. The "memory" only lasts for a short period of time, e.g. 15 seconds, for the fever scope application before the composition reverts to its original colour.

In the fever scope 1, the third thermochromic liquid

crystal composition typically has a clearing point of 34.5°C, the second thermochromic liquid crystal composition typically has a clearing point of 36°C and the first thermochromic liquid crystal composition typically has a clearing point of 45°C. The fever scope is intended for measuring forehead temperature (which is generally from 2-2.5°C lower than the corresponding internal body temperature). Forehead temperatures below 34.5°C are considered to be normal ("N") whereas forehead temperatures above 34.5°C suggest that the user has a fever ("F"). Forehead temperatures in excess of 36°C suggest that the user has a very high temperature ("F+").

In use of the fever scope 1, the user's forehead temperature is taken by placing the fever scope 1 against the forehead for approximately 30 seconds with the backing sheet in contact with the forehead and the transparent upper or outer layer 2 facing outwards. Whilst the fever scope 1 is against the forehead, the three thermochromic liquid crystal compositions are heated to the temperature of the forehead and any of three conditions will be displayed. If the forehead temperature is below 34.5°C, regions 3a, 3b, 4a, 4b and 5 will all display the same colour since the three liquid crystal compositions are all at temperatures below their respective clearing points. In the case where the liquid crystal compositions display a light green colour when at temperatures below their clearing point and the light absorbing backing layer is black, a black letter "N" (designated 7 in Figure 2) will be visible from the front through the window 5a of the region 5, the rest of the display showing a light green colouration (designated 8 in Figure 2). If the forehead temperature is above 34.5°C but below 36°C, the region 5 of the third thermochromic crystal composition will be transparent since the clearing point of the third liquid crystal composition will have been exceeded. A light green letter "F" (designated 9 in

Figure 3) and provided by region 4a (Figure 1C) is therefore displayed against a black background 10 covering part of the display. The remaining part of the display covered by regions 4b, 3a and 3b will, however, remain
5 light green, as designated by reference numeral 11 in Figure 3. If the forehead temperature is above 36°C (and below 45°C), the clearing points of both the second and third thermochromic liquid crystal compositions will have been exceeded and a light green "F+" (designated
10 13 in Figure 4) and provided by regions 3a and 3b (Figure 1A) will be displayed against a completely black background 14.

The clearing point of the first thermochromic liquid crystal composition is deliberately chosen so as not
15 to be exceeded under normal operating temperatures of the fever scope. If this clearing point (i.e. 45°C) were to be exceeded, the display device would display a black colouration all over, since all the liquid crystal compositions would have been rendered transparent.

20 The "memory" of the liquid crystal compositions and/or of the fever scope 1 ensures that the display can be read for a period of time, e.g. up to 15 seconds, after the fever scope 1 has been removed from the user's forehead.

25 It will be appreciated that there is precise switching between the various display modes as the temperature of the device passes through the various clearing points of the liquid crystal compositions. Thus as 34.5°C is passed through, the display switches abruptly from the display shown in Figure 2 to that shown in Figure 3.
30 Similarly as 36°C is passed through, the display switches abruptly from the display shown in Figure 3 to that shown in Figure 4.

In the fever scope 1 described herein, the regions

3a, 3b, 4a, 4b and 5 and the light absorbing backing layer have been printed directly onto the inner surface of the transparent front layer. It is possible, although less desirable, to print these layers in the reverse order onto a back carrier sheet. In this case, however, the front covering layer would have to be laminated onto the overprinted back carrier sheet using clear adhesive or, alternatively, a clear lacquer applied in place of the front covering layer of sheet material. The various regions of thermochromic liquid crystal compositions applied over the backing layer would of course be mirror images of the regions shown in Figures 1A to 1C.

The techniques described herein with reference to the fever scope 1 can be applied to other temperature responsive display devices. For example an oral thermometer can be constructed in a similar manner, although in this case the backing layer or carrier would have a degree of rigidity and would have the form of a spatula for insertion into the mouth. The thermochromic liquid crystal compositions would only be provided to cover a relatively small area, e.g. 2 cm^2 , at one end of the spatula like carrier, and the clearing points would be adjusted to measure internal body temperature instead of forehead temperature.

Another application is illustrated in Figure 5 which shows a thermometer 20, in the shape of a conventional mercury-type room thermometer, having a circular bulb portion 21, an elongate tube portion 22 and a rectangular carrier 23. The carrier 23 may be printed with a light absorbing layer 24, typically a black layer, over the entire bulb portion 21 and tube portion 22, the layer 24 then being overprinted with thirteen rectangular portions a - m of different thermochromic liquid crystal compositions which are finally covered with a transparent protective layer. Preferably, however, the various por-

tions a to m will be printed onto the inner surface of a transparent flexible front layer of plastics material, e.g. PVC sheet material, having the same length and width of the carrier 23. The light absorbing layer 24, e.g. of black printing ink, will then be printed over the portions a to m and over the circular bulb portion 21. Finally the printed front layer is adhered to the carrier 23 with the light absorbing layer facing the carrier 23. As a preliminary printing operation, before the printing of regions a to m, graphic information, e.g. the figures indicating the temperatures in °C, may be printed onto the inner surface of the transparent front layer. As with the fever scope 1, the thermochromic liquid crystal compositions have a low temperature dependence of colour and display substantially the same colour over wide temperature ranges below their respective clearing points. In the thermometer illustrated, the clearing points of the liquid crystal compositions increase successively for regions a to m in steps of 2°C from a clearing point of 12°C for the composition of region a to a clearing point of 36°C for the composition of region m. The regions a to m may be printed without overlap, but preferably at least adjacent regions have a degree of overlap so that there are no gaps between adjacent regions.

In use of the thermometer 20, different numbers of the regions a to m will be rendered transparent in dependence on the number of clearing points that are exceeded when a particular ambient temperature is sensed. For example if the ambient temperature is below 12°C, all the regions a to m will appear the same colour, e.g. light green, when subjected to incident white light, and only bulb portion 21 will appear black. If the ambient temperature is at 22°C, regions a to f will be rendered transparent and the underlying black layer 24 will be visible, whereas regions g to m will remain the same

colour, e.g. light green in appearance. Thus as ambient air temperature increases, successive regions a to m will be rendered transparent as their clearing points are exceeded, and a black line will move up the portion

5 22. With such a thermometer, it is preferable that the thermochromic liquid crystal compositions and/or the thermometer have little or no memory and that the temperature at which each composition reverts to a liquid crystal phase, e.g. a cholesteric phase, from its isotropic state

10 is the same as its clearing point.

In other applications, a filter layer may be employed to enable different colours to be displayed or to obtain a better colour match between different thermochromic liquid crystal compositions.

15 According to another aspect of the present invention there is provided a temperature responsive display device for providing a display over a temperature display range, the display device comprising a light absorbing backing layer and, arranged, e.g. printed, in from of the backing

20 layer, at least one thermochromic liquid crystal composition having a clearing point in said temperature display range, the or each thermochromic liquid crystal composition displaying, when subjected to incident white light, a given colour over a wide range of temperatures immediately below the or its clearing point, said displayed

25 colour contrasting with the light absorbing backing layer, whereby when the display device is subjected to an elevated temperature, the or each liquid crystal composition masks the underlying light absorbing backing layer until

30 the temperature of the or each composition reaches its clearing point.

CLAIMS

1. A temperature responsive display device comprising a light absorbing backing layer and, arranged in front of the latter, at least two thermochromic liquid crystal compositions having different clearing points
5 which mask the backing layer, at least one of the clearing points being selected to be in the normal operating temperature range of the display device, whereby, when the display device is subjected to incident light and the temperature of the display device is elevated from a
10 temperature below the lowest clearing point to a temperature above the highest clearing point, an increasing proportion of the backing layer is revealed as the various clearing points are passed through, the display visible at any stage of the temperature elevation being provided
15 by the contrast between any thermochromic liquid crystal composition which has not been rendered transparent and the light absorbing backing layer visible directly or through portions of the overlying liquid crystal compositions which have been rendered transparent.

20 2. A display device according to claim 1, in which the thermochromic liquid crystal compositions are of the type which have a low temperature dependence of colour.

3. A display device according to claim 2, in which said thermochromic liquid crystal compositions are
25 selected to display the same colour over wide temperature ranges immediately below their respective clearing points when subjected to incident white light.

4. A display device according to claim 3, in which the said same colour is chosen to have a high contrast
30 with the light-absorbing backing layer.

5. A display device according to any one of the preceding claims, in which the thermochromic liquid crystal compositions employed are of the "memory" type,

each composition having a "memory" for a period of time after its temperature is lowered below its clearing point.

5 6. A display device according to claim 5, in which the said "memory" is provided by the addition of cholesteric additives to the thermochromic liquid crystal compositions.

10 7. A display device according to claim 5, in which the liquid crystal compositions are sandwiched between sheets of high thermal inertia material, the type and thickness of such thermal inertia material determining the particular "memory".

15 8. A temperature responsive display device constructed and arranged substantially as herein described with reference to, and as illustrated in, Figures 1A - 1D, 2, 3 and 4 or Figure 5 of the accompanying drawings.